

Testing Goals to Support Engineered Residual Stress Integration into ASIP

1st Annual ERSI Workshop

15 Sept 2016

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Contents

- Accomplishments
 - Understanding fatigue at CX holes
 - Modeling advancements
- What is missing?
- Need open discussion on:
 - What factors are important to model?
 - What testing would identify factors?
 - What testing would validate models?

Lots of Folks doing Lots of Stuff


- Decades of research into life improvement from CX processes at fatigue-loaded holes
 - The deepest bodies of work are proprietary
- Since 2006: USAF-supported efforts....
 - Isolating major sources of variation in fatigue performance
 - Edge margin
 - Interference level
 - Maximum remotely applied stress
 - Typical goal was to understand CX performance relative to current USAF ASIP guidance, “0.005”
 - Understanding Failure Progression
 - Crack formation locations
 - Crack propagation behavior
 - Evolution of shapes
 - Variations resulting from constant amplitude vs. spectrum load
 - Public Domain



<http://www.a-listinternational.com/motivation-monday-how-to-be-a-great-team-player/>

Simulating What We See

we think

- Primary technical advancements of the last decade
 - High-density residual stress data (Contour Method)
 - Integrated multi-point crack growth
 - Allows crack front to take natural shape
 - Not forced to be semi-elliptical
 - USAF focused on integrating StressCheck / AFGROW using 
 - Computation of stress intensity for crack in residual stress fields
 - A-10 & T-38 ASIP utilize StressCheck
 - J-integral and Contour Integral Method for Loaded Cracks (CIM-LC) **
 - CIM-LC only requires one component of RS tensor, which is important when using Contour Method data, as it supplies one component.

The Future of CX Experimental Programs

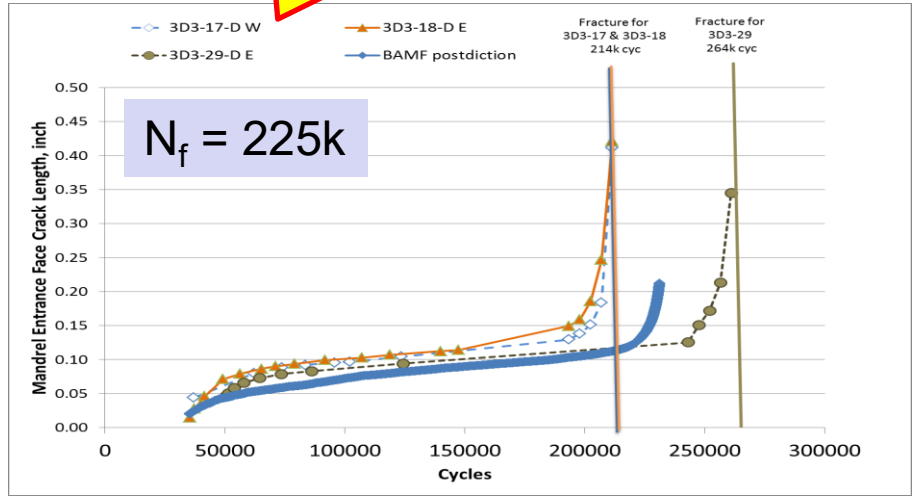
- Experimental work....
 - Illustrates important factors to model
 - Provides data so we can validate models
- One advantage of having completed extensive fatigue tests in CX holes:
 - Creates many questions that we can go answer.
- Topic Areas
 - Many currently identified
 - Need input from working group

Experiments to Support Modeling Needs

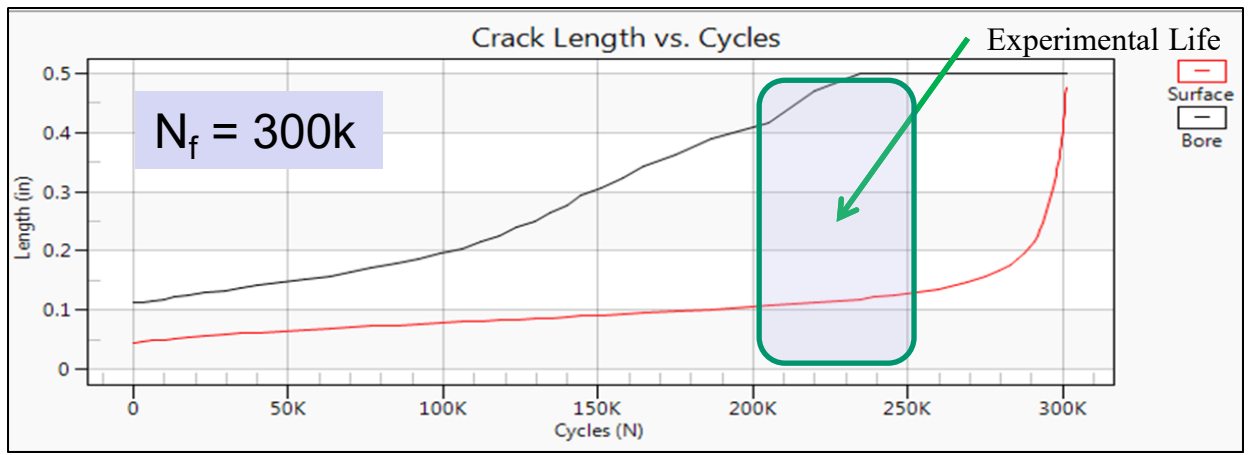
- Material Behavior
- Residual Stress Redistribution
- Countersunk holes (95% of USAF efforts in straight-bore holes)
- Other CX Processes
- Other Engineered RS Processes

Material Model Sensitivity

- da/dN vs. ΔK relationships have major impact on predicted life
- In this example, BAMF using material model 1 (MM1) computed a life that is 75% of that of CPT and MM2

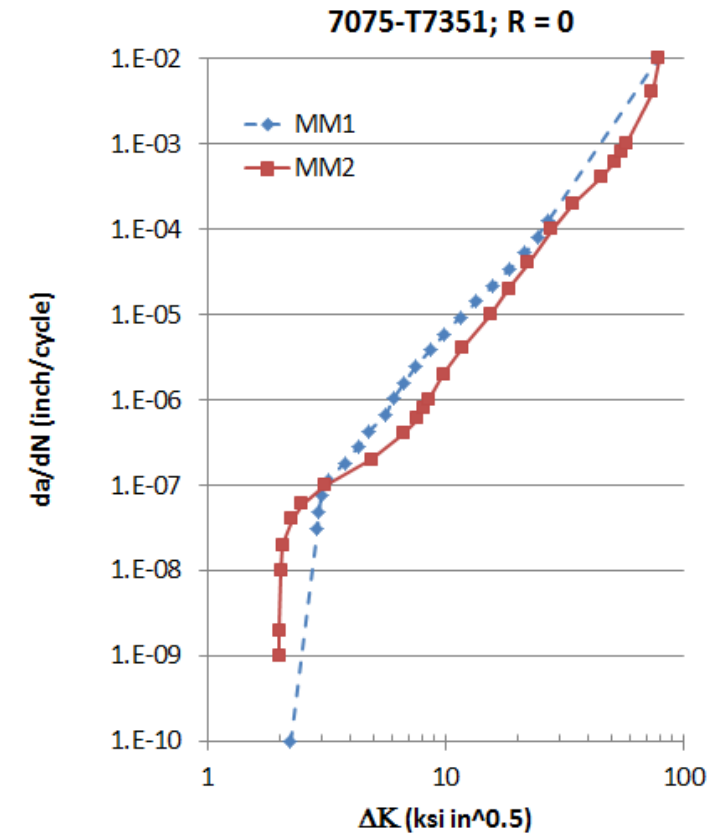


CPT



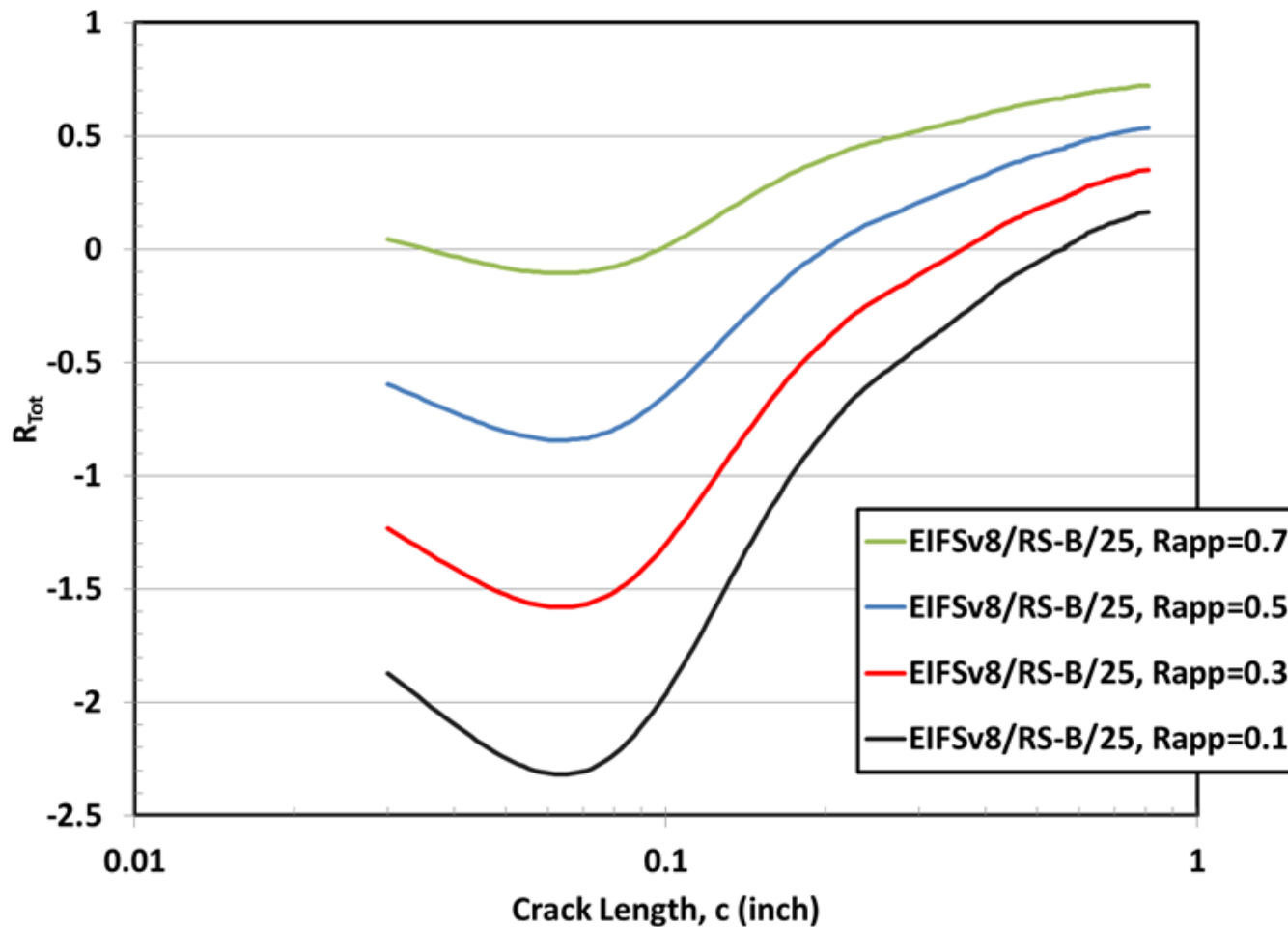
Thorough da/dN v. ΔK Curves

- History of long crack data with severe “threshold” behavior
- High R data
 - Not as critical to RS applications because K_{res} typically pushes R_{tot} negative)
- Weak on Negative R data
 - K_{res} pushes R_{tot} deeply negative
 - Not a typical consideration in tension-dominated DT control points

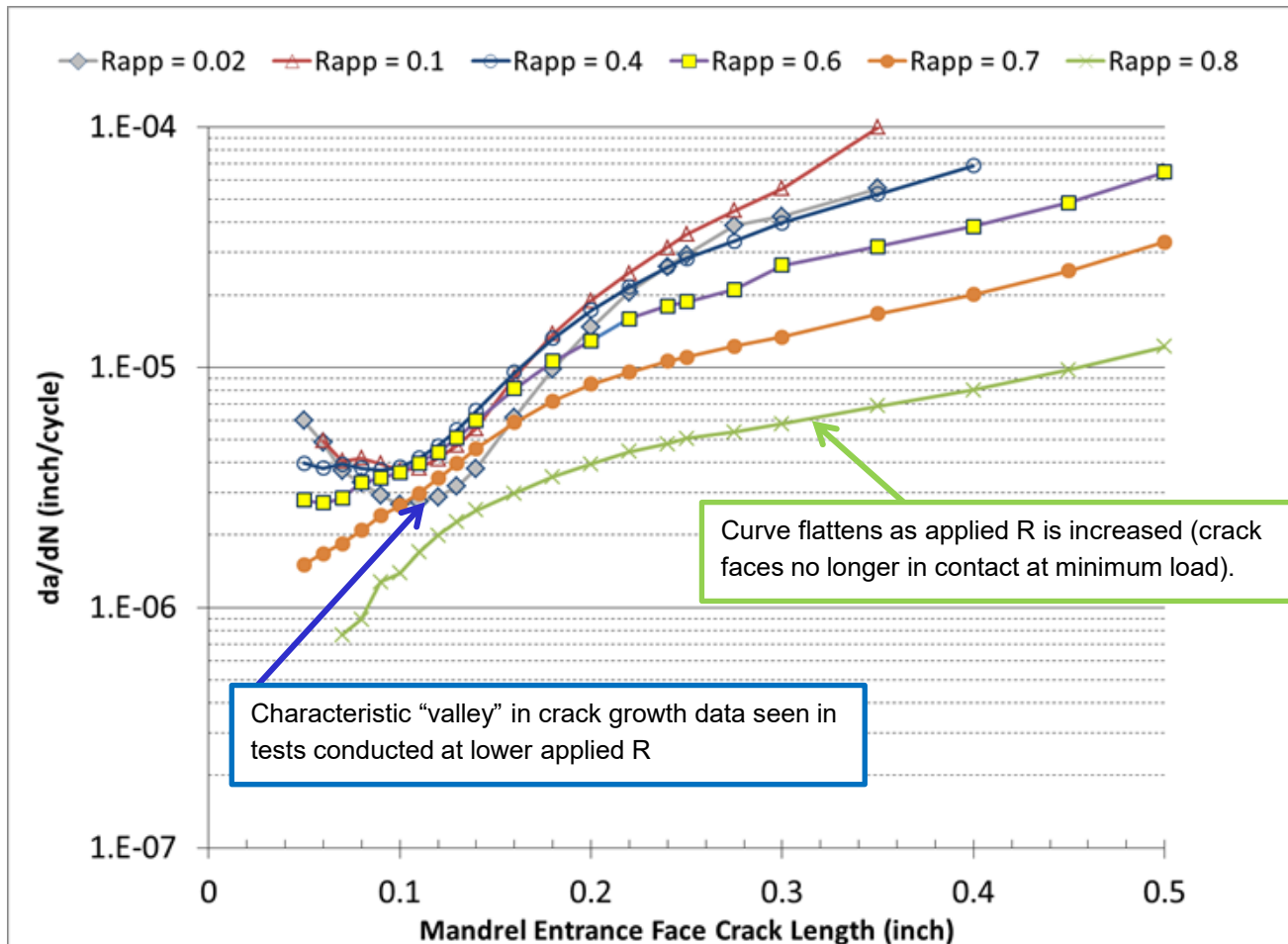


Relationship of Crack Size and Total R

- Example using 3.8% CX interference and 25 ksi remotely applied stress (varying applied R, R_{app}).



Evidence of Closure Processes?

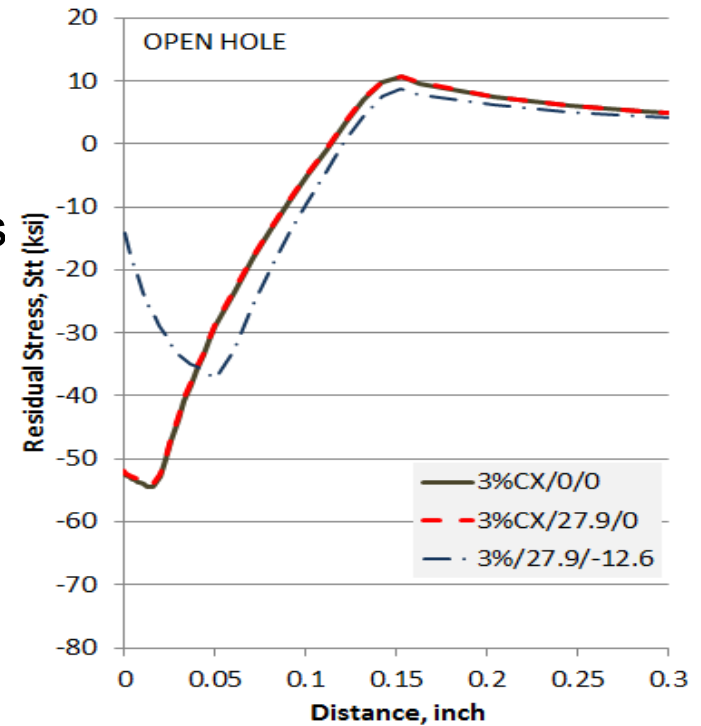


Other Material Behavior Considerations

- Modeling of CX process
 - RS distribution sensitive to “hardening parameter”
 - Kinematic vs. isotropic
- Closure
 - Characteristic “hook” in da/dN vs. ‘a’ data disappears at high applied R ($R_{app} > 0.7$)
- Retardation
 - Commonly used in DTA
 - Proper application for RS cases?

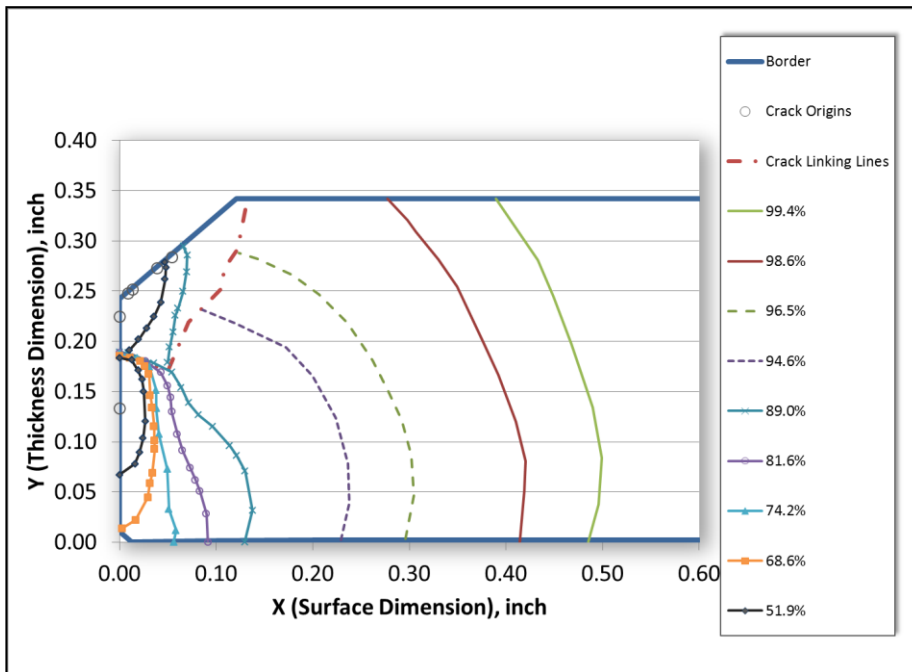
Residual Stress Redistribution and Interactions

- Load spectra
 - Peak tension and compression effects
 - How do stresses redistribute?
 - Open hole
 - Filled hole
 - Load transfer
- Stress interaction
 - CX holes and interference pins
 - RS distributions and nearby geometric effects (moving failure)
 - Re-working a CX hole
- *At least one* dissertation here just for straight-bore holes.
 - Somebody can get another dissertation for countersunk holes

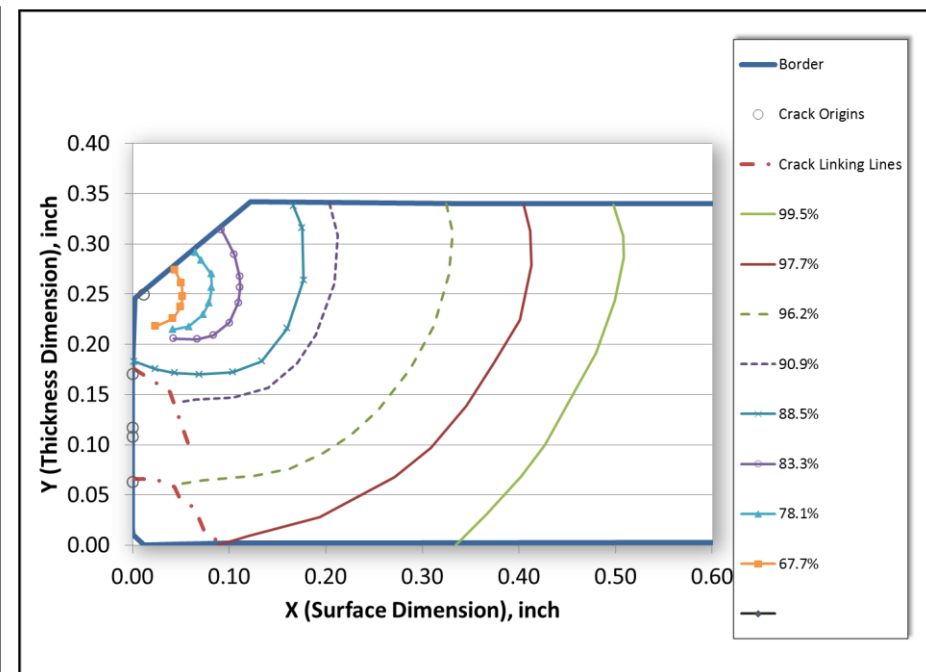


Speaking of Countersunk Holes....

- Fatigue origins (and life) are sensitive to CX method.



- CX straight bore hole, then machine countersink
- Modeling redistribution of RS when material is removed?



- CX existing countersunk hole using FTI's CsCX

Left: crack growth inhibited at countersink knee despite higher Kt.

Other RS Methods

- Current efforts have mostly focused on split sleeve CX of fastener holes
- Laser Peening
 - Hill Engineering has done some work in this area
- Other CX processes (split mandrel)?
- Other surface RS methods?
 - Many of these would not be friendly to damage tolerance analyses
 - Stress not deep enough

“Legacy” CX Holes

- Building a robust toolbox based on “new build” scenarios and data.
- What if holes were CX’d in days of yore?
- Some effort underway to look at RS of legacy CX holes
 - Teardown wings from T-38 & A-10
- Fatigue response to be examined as well

As we prepare to open discussion....

- USAF current contracted efforts are examining the following:
 - RS redistribution from external loads and pin loads (limited capacity)
 - Material model deficiencies (da/dN vs. ΔK)
 - Some work in countersunk holes
 - Some legacy CX considerations
- Goal here is get feedback on other important test data needed for validation or for exploring pitfalls
- Road to ASIP integration